A METHOD FOR THE STATISTICAL ESTIMATION OF THE TRAFFIC DISPERSION IN TELECOMMUNICATION NETWORK

Field of the invention

The invention relates to techniques for evaluating traffic dispersion in telecommunication networks.

The present invention was developed by paying specific attention to the possible preferred use in circuit switched telecommunication networks. As used herein, "circuit switched" is intended to cover at large the concept of switching implemented by establishing a physical link between a calling party (source) and a called party (destination) and, as such, also extends to e.g. mobile communications networks applying that switching concept.

Description of the related art

Measurements of traffic dispersion can essentially be organized in two forms:

- measuring the amounts of traffic flows towards each destination which make up the whole traffic carried by a circuit group;

- measuring the amounts of traffic flows towards a single destination carried by one or more circuit groups, depending on the routing rule applied.

Network exchange nodes usually generate traffic dispersion measurements. These measurements, however, typically suffer from some major limitations:

- the number of objects simultaneously measured (i.e. traffic flows) is usually limited due to system constraints and high processing capacity needs;

- in the presence of a high traffic level in the network, exchanges may stop non-priority processes to prevent system instability: consequently, traffic dispersion measurements may be discontinued by the

system, and this occurs just when they would be most useful; and

- each exchange measures its own traffic dispersion, without the capability of producing measurements related to the traffic dispersion from a network point of view.

A number of Recommendations of the Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T) are related to traffic engineering and measurement. Specifically, the following ITU-T documents provide definitions, principles and requirements for traffic measurements in a telecommunication network., e.g.:

- ITU-T Recommendation E.491 - Traffic measurement by destination - (05/1997)

- ITU-T Recommendation E.500 - Traffic intensity measurement principles - (11/1998)

- ITU-T Recommendation E.502 - Traffic measurement requirements for digital telecommunication exchanges - (02/2001)

- ITU-T Recommendation E.600 - Terms and definitions of traffic engineering - (03/1993)

More in detail:

- Recommendation E.491 defines the destination concept and the associated traffic measurements;

- Recommendation E.500 defines methods and principles used to generate, analyse and collect traffic measurements;

- Recommendation E.502 defines requirements for digital telecommunication exchanges in terms of which and how traffic measurements should be made

All the documents listed are related to traffic measurements effected with telecommunication exchanges.

In US-A-5 359 649 a system is disclosed for optimising the traffic carrying capacity of a telecommunications network having a plurality of elements and a plurality of routes connecting those

elements to one another. The controlled congestion in the network is controlled by identifying and limiting defective devices and routes with exaggerated levels of congestion. Disturbance alarm levels are also adjusted to allow increased traffic through the network. The traffic within the network is reconfigured in real time in response to the occurrence of network events to optimize traffic capacity.

Objects and summary of the invention

The need is thus felt for arrangements that may provide, preferably at a centralised level, an evaluation of the dispersion of traffic within a network such as a circuit-switched network. The availability of such a tool is significant for telecommunication network operators in planning, designing, operating and managing such networks.

In fact, circuit-switched network are known to be exposed to overflow phenomena that i.a. render the basic models currently adopted for "traffic engineering" no longer applicable.

More to the point, the need exists for arrangements that may generate reliable indicators of traffic dispersion without involving network equipment (and thus generating undesired additional load in that equipment).

The object of the present invention is to satisfy such needs.

According to the present invention, that object is achieved by means of a method having the features set forth in the claims that follow. The present invention also related to corresponding system and network, as well as to a computer program product loadable in the memory of at least one computer and including software code portions for performing the method of the invention when the product is run on a computer.

A preferred embodiment of the invention is a system that acquires the following information from the exchange nodes of the telecommunication network:

- traffic measurement on destinations and circuit groups, which are available in most network conditions with very few limitations; and

- routing rules used by the exchange nodes to distribute traffic directed to each destination on the different circuit groups.

Such a system then generates a statistical estimation of the traffic dispersion starting from destination and circuit groups measurements, and the routing rules used by each destination to route traffic over the available circuit groups.

The foregoing provides for the statistical estimation of a set of measurements, some of which may not be available in an exchange; these measurements can however be obtained outside the network nodes starting from a subset of traffic measurement.

The main advantages of the arrangement considered are:

- no limitations apply to the number of destinations and circuit groups involved in the traffic dispersion evaluation: in fact, no appreciable processing capacity needed for this task is drawn from network exchanges;

- the system acquires information from all the exchange nodes in the network; this gives the possibility of generating traffic dispersion information on a network basis that is not currently available at exchange nodes.

The system disclosed herein generates a statistical estimation of the traffic dispersion since only the exchange itself is able to measure the traffic dispersion without uncertainty.

Brief description of the drawings

The invention will now be described with

reference to the annexed figures of drawing, wherein:

- figure 1 is a basic block diagram of a telecommunication network,

- figure 2 and 3 are functional block diagrams showing the typical architectural layout of a network node and a system arranged to perform the method disclosed herein,

- figures 4 to 6 are flowcharts exemplifying certain steps performed in the method disclosed herein,

- figure 7 is a schematic flow diagram exemplifying the meaning of some entities evaluated in the method disclosed herein, and

- figures 8 and 9 are further flowcharts exemplifying further steps performed in the method disclosed herein.

Detailed description of preferred embodiments of the invention

Figure 1 is a basic block diagram of a telecommunication network N including a plurality of nodes each equipped with a respective exchange 1, 2, 3, . . ., n.

Specifically, the exchanges in question network are configured (in manner largely known per se) in order to cause the network N to operate as a circuit switched telecommunication network.

As already indicated, "circuit switched" is intended to cover at large the concept of switching implemented by establishing a physical link between a calling party (source) and a called party (destination) and, as such, also extends to e.g. mobile communications networks applying that switching concept.

Exemplary of such a network is the "fixed" part of a mobile telecommunication network operating according to the GSM (Global System for Mobile communications) standard. In such a network the nodes/exchanges shown

may be actually represented by MSC/VLR and/or TR/TSP modules. As is well known, these acronyms stand for Mobile Switching Center, Visitor Location Register, TRansit point and Signalling Transfer Point, respectively.

It will be appreciated that reference to this specific, possible context of application is in no way to be construed as limiting the scope of the invention.

In a network N as shown in figure 1, conventional measurements of traffic dispersion essentially provide for:

- measuring the amounts of traffic flows towards each destination which make up the whole traffic carried by a "link" as represented e.g. by a circuit group (for example: the traffic flowing from node 1 to node 2, irrespective of whether this is eventually sent to any of nodes 4, 5, or n); and

- measuring the amounts of traffic flows towards a single destination carried by one or more circuit groups, depending on the routing rule applied (for example: the traffic from node 1 to node 4, irrespective of whether this is routed via node 2 or node 3).

The arrangement disclosed herein has the purpose of providing more analytical indications concerning the dispersion of traffic over the whole network. By referring to the examples just made, such more analytical indications may include e.g.:

- an indication of the amounts of traffic from node 1 to node 4 that are routed via the node 2 and via the node 3, respectively, or

- an indication of what portions of the traffic flowing from node 1 to node 2 are possibly sent towards any of nodes 4, 5, or n.

In the arrangement disclosed herein, at least some of

the nodes in the network N (in figures 2 and 3, a generic node/exchange designated EX_k is shown), are configured in order to permit extraction of the configuration data 10 (essentially, the routing rules) and - from the measurements already currently available at each exchange - the performance data 12 (essentially, the conventional measurement data mentioned in the foregoing).

The processing tasks related to generating the routing rules can be performed by resorting e.g. to the arrangement disclosed in WO-A-02/071779 and in Italian patent application TO20002A000742.

In figure 2, processing modules adapted to perform the functions of configuration data verification and analysis as well as the function of generating the routing rules are designated by the reference numerals 14 and 16. Based on the output from the module 14 and the performance data 12, the module 16 is adapted to provide an evaluation of traffic dispersion data as better detailed in the following.

Even though intended to co-operate with one or more of the exchanges/nodes in the network, these modules can in fact be thoroughly independent entities from the network exchange(s)/node(s): all of the processing tasks described in the following can thus be carried out without producing any additional, undesired workload in the exchange(s)/node(s) in question.

A preferred mode of operation of the arrangement disclosed herein essentially includes two main, sequential phases:

- a first phase, wherein the estimated traffic dispersion is evaluated on a "per exchange" basis, i.e. by generating a traffic dispersion estimation independently for each exchange (node) of the telecommunication network, and

- a second phase, wherein, by collecting in a centralized system the input and output data of the first phase, a more detailed traffic dispersion estimation on a network basis is generated where the traffic towards each destination is further divided depending on the source of the traffic, e.g. the exchange where the traffic originated.

The routing rules generation module 14 analyses the exchange configuration data 10 taken from the exchange EX_k. Starting from routing configuration data CF_k during a routing rules generation process RG, the module 14 produces the routing rules RL_k proper. These rules specify, what traffic directed towards a certain destination is distributed over a defined set of circuit groups ("links") and how this distribution is performed.

The module 14 is used only to produce the input data for the traffic dispersion evaluation module 16 and analyse the configuration data 10: hence, it has to be used only when such configuration data change in the telecommunication network.

The traffic dispersion evaluation module 16 analyzes two kinds of data, i.e.:

- the routing rules RL_k generated from the configuration data 10 by the module 14; and
- the traffic measurements TM_k on destinations and circuit groups generated by the exchange EX_k.

These two kinds of information are used in a traffic dispersion evaluation step TDE to estimate the traffic dispersion. The corresponding information TD_k is conceptually a matrix where rows represent traffic destinations and columns represents circuit groups: each crossing (destination "x", circuit group "y") contains the traffic volume direct towards destination "x" and carried by circuit group "y".

The traffic dispersion evaluation module 16 generates a new instance in the estimated traffic dispersion matrix each time a new set of measurements is available from the exchange EX_k (usually 5, 10 or 15 minutes).

In that respect, it will be appreciated that routing rules are usually fairly stable over time, except when configuration data are changed in the network; this is why the routing rules generation module 14 can be seen as a "preparation" module.

The routing rules generation module 14 analyses the configuration data 10 of the exchange in order to generate for each traffic destination the routing rule. Each routing rule, used by one or more traffic destinations, basically contains the following information:

- the set of circuit groups available for traffic routing;
- the priority associated to each circuit group when overflow is configured; and
- the percentage load associated to each circuit group when load sharing is configured.

The routing rules generation module checks if at least one of the following conditions is met:

- for each traffic destination there is one and only one routing rule;
- for each traffic destination there are two routing rules but one is a subset of the other and the highest priority circuit groups are common to both routing rules: in this case the routing rule containing the "superset" of circuit groups is assumed.

In general, the latter condition is valid for several routing rules where the first rule is a subset of a second one, which in turn is a subset of a third rule and so on, and the highest priority circuit groups are common to all routing rules. In this case, the routing

rule containing the superset of circuit groups is assumed.

If none of the above conditions is met, then a modification in the exchange configuration data 10 is carried out in order to modify the traffic destination and/or the relevant routing data.

The traffic dispersion evaluation module 16 performs a statistical evaluation of the traffic dispersion with the following input data:

- the set of routing rules used by the exchange to route the traffic towards each destination, as generated by the routing rules generation module 14;

- traffic measurements generated by the exchange EX_k, namely:

- for each destination: traffic volume; and

- for each circuit group: outgoing traffic volume, outgoing call attempts, outgoing seizures, number of available circuits on the circuit group.

In order to evaluate the estimated traffic dispersion on each circuit group (even in the presence of overflow on one or more circuit group) the method shown in figures 4, 5, and 6 is used.

The method is iterative and, starting from a "start" step 100, is repeated for each circuit group as shown in 102.

The method is based on an incremental load distribution approach: during each loop step, for each traffic destination, a corresponding traffic volume divided by the total number of loop steps is considered; this traffic "quantum" is assigned to the relevant circuit group according to the routing rule associated to the destination.

Overflows on circuit groups are detected in a step 104 by comparing the number of call attempts and the number of seizures.

Hence, for each circuit group there can be two conditions:

- the number of call attempts equals the number of seizures (positive outcome of step 104): no overflow has occurred;

- the number of call attempts is greater than the number of seizures (negative outcome of step 104): overflow has occurred.

In the former case, in a step 106 the load limit on the current circuit group is set equal to the number of circuits available in the circuit group.

In the latter case, in a step 108 the limit in question is set equal to the outgoing traffic volume measured on the circuit group.

Traffic "quantums" are accepted on the circuit group only if the sum of all the traffic portions assigned to that circuit group is smaller than the outgoing traffic volume measured by the exchange on the same link, i.e. on the same circuit group; otherwise, the next choice in the routing rule is selected and the same is applied to the new circuit group.

In figure 4, step 110 indicates the end of the loop started in step 102 while 112 indicates an end step.

The flowcharts of figures 5 and 6 show a traffic dispersion evaluation method adapted to be performed by using the incremental load distribution approach described in the foregoing.

Considering first of all figure 5, after a start step 200, two "nested" loops are started in steps 202 and 204, the outer loop being rated to the number of loop steps the method is repeated, while inner loop is repeated for each traffic destination.

In a step 206, the current routing rule used by the exchange to route the current destination is selected. In a subsequent step 208 the "quantum" of traffic is calculated as the ratio of the traffic volume measured for the current destination to the product of the number of loop steps and the load sharing percentage.

In a subsequent step 210 the traffic quantum thus

calculated is distributed with the current routing rule as better detailed in the flow chart of figure 6. References 212 and 214 represent the ends of the inner loop and the outer loop started at steps 204 and 202, respectively. Reference 216 represents an end phase.

By referring now to the flowchart of figure 6, after a start step 300, in a step 302 the first choice circuit group in the current routing rule is selected.

In a subsequent step 304 a comparison is made in order to ascertain whether, for the current circuit group, the sum of the traffic loaded and the traffic quantum is less or equal to the load limit of the current circuit (defined as described with reference to figure 4).

In the case of a negative outcome of step 304, in a step 306 the next choice circuit group in the current routing rule is selected, after which the system evolves back upstream of step 304.

In the case of a positive outcome of step 304, in a step 308 the amount of traffic quantum is added to the traffic loaded for the current circuit group and in a step 310 the amount of the traffic quantum is added to the traffic distribution for the current destination and the current circuit group. As in the diagrams of figures 4 and 5, a reference 312 designates an end step.

The traffic dispersion evaluation on a network basis relies on results and assumptions of the traffic dispersion on a "per exchange" basis.

The method adopted for evaluating the traffic dispersion on a network basis can be described by referring to the example shown in figure 7.

There, three digital exchanges, namely EX_k, EX_m and EX_n, are shown with an associated subset of circuit groups:

- CG_p interconnecting EX_m and EX_k;

- CG_r interconnecting EX_n and EX_k; and
- CG_y interconnecting EX_k and another generic exchange.

At each exchange, the traffic volume directed towards the destination "x" is considered, namely:

- TV_{kx}, i.e. the traffic volume directed towards the destination "x" in the exchange EX_k;
- TV_{mx}, i.e. the traffic volume directed towards the destination "x" in the exchange EX_m; and
- TV_{nx}, i.e. the traffic volume directed towards the destination "x" in the exchange EX_n;

Once the traffic dispersion evaluation on a per exchange basis is available for the exchanges EX_k, EX_m and EX_n, the following estimated results can be derived:

- TV_{kxy}, i.e. the traffic volume directed towards the destination "x" in the exchange EX_k,and carried by the circuit group CG_y: TV_{kxy} is generally a portion of TV_{kx};
- TV_{mxp}, i.e. the traffic volume directed towards the destination "x" in the exchange EX_m, and carried by the circuit group CG_p: TV_{mxp} is generally a portion of TV_{mx}; and
- TV_{nxr}, i.e. the traffic volume directed towards the destination "x" in the exchange EX_n, and carried by the circuit group CG_r: again, TV_{nxr} is generally a portion of TV_{nx}.

The traffic volume TV_{kxy} is made up of at least three components:

- the traffic volume directed towards destination "x" in exchange EX_k, carried out by the circuit group CG_y, originating from EX_k itself;
- traffic volume directed towards destination "x" in exchange EX_k, carried out by the circuit group CG_y, incoming from exchange EX_m and carried in by the circuit group CG_p; and
- the traffic volume directed towards destination "x" in exchange EX_k, carried out by the circuit group CG_y,

incoming from EX_n and carried in by the circuit group CG_r.

The traffic volume TV_{kxy}, which is the result of the traffic dispersion evaluation on the exchange EX_k, can be further decomposed using the results and information from the traffic dispersion on each of the exchanges EX_m and EX_n, and the relevant circuit groups interconnecting each couple of exchanges.

The evaluation of traffic dispersion on a network basis is done for each exchange with the following method.

The traffic volume towards each destination is considered (e.g. TV_{kx}). For each destination the various traffic volume components incoming from the various circuit groups are considered:

- TV_{mxp} incoming from EX_m;
- TV_{nxr} incoming from EX_n; and
- the traffic component originating in EX_k, namely, TV_{kxk} that can be obtained as the difference:

$$TV_{kxk} = TV_{kx} - (TV_{mxp} + TV_{nxr})$$

These components have the same routing rule in the exchange or some of them have a subset of the routing rule. Under this condition two groups of traffic components are created, namely:

- a first group A, including traffic components using the subset of circuit groups in the routing rule;
- a second group B including traffic components using the whole set of circuit groups in the routing rule.

The traffic components of group A are spread on a subset of circuit groups with respect to those of group B; hence they are considered first in the following algorithm.

In general, if there are more than two routing rules for a generic traffic volume, like TV_{kxy}, each one included in another, there will be more than two groups of traffic components. The algorithm will consider each group of traffic components starting from the group

which is routed by means of the smallest set of circuit groups.

Specifically, the following example will be considered with reference to the exchange EX_k.

Consider the traffic volume TV_{kxy} directed towards the destination x and carried by the circuit group CG_y; the routing rules used for the three traffic components lead to the following groups:

Group A = TV_{mxp};

Group B = TV_{nxr} and TV_{kxk}

Then the component of traffic volume TV_{kxy} coming from EX_m, namely $TV_{kxy,m}$ can be obtained as:

$$TV_{kxy,m} = \frac{TV_{mxp} \times TV_{kxy}}{\sum_{\delta}^{\forall CG \in \Delta} TV_{kx\delta}}$$

where Δ is the subset of circuit groups used by the current routing rule.

The sum of all the results obtained as before on each circuit group of the routing rule and related to traffic components in group A ($TV_{kxy,A}$) is then calculated and used in the following steps:

$$TV_{kxy,A} = \sum_{\alpha}^{\forall \alpha \in A} TV_{kxy,\alpha}$$

The components related to group B may then be calculated; for example the component of traffic volume TV_{kxy} coming from EX_n, namely $TV_{kxy,n}$:

$$TV_{kxy,n} = \frac{TV_{nxr} \times \left(TV_{kxy} - TV_{kxy,A}\right)}{\sum_{\delta}^{\forall CG \in \Phi} \left(TV_{kx\delta} - TV_{kx\delta,A}\right)}$$

where Φ is the whole set of circuit groups used by the current routing rule.

A flowchart of the method described is shown in figures 8 and 9.

Specifically, in figure 8, after a start step 400, two nested loops are again started at the steps 402 and 404. Specifically, the outer loop is repeated for each traffic destination, while the inner loop is repeated for each incoming traffic component.

In a step 406 the current routing rule is selected as used by the exchange considered to route the current traffic component.

In a subsequent step 408 a check is made as to whether the current routing rule is a subset of the whole rule used for the traffic dispersion evaluation.

If step 408 yields a positive outcome, the current traffic component is added to the group A in a step 410.

If the step 408 yields a negative result, the current traffic component is added to group B in a step 412.

Steps 414 and 416 designate the ends of the inner loop and outer loop started at steps 404 and 402, respectively. Again, step 418 marks the end of the process.

In the flowchart of figure 9, after a start step 500, a step 502 indicates the start of a loop to be repeated for each traffic destination, while in a step 504 another loop is started to be repeated for each incoming traffic component allotted to group A.

In a step 506 a network distribution for the current traffic component and the associated routing rule is calculated.

Step 508 marks the end of the loop started at step 504, while in a subsequent step 510 another loop is started to be repeated for each incoming traffic components in group B.

In a step 512 the network distribution for the current traffic component and the associated routing rule is calculated.

Step 514 marks the end of the loop started at step 510.

Step designated 516 marks the end of the loop started at step 502. Again, a step 518 marks the end of the process.

This approach can be extended insofar as needed in order to decompose traffic volumes keeping into account other exchanges in addition to the exchange located immediately "upstream" in the traffic flow path.

The selection of a centralised architecture for the system just described is advantageous in order to guarantee the availability at the same location of all the information required, i.e.:

- the traffic dispersion evaluation on a "per exchange" basis for all the exchanges of interest;

- the network architecture in terms of exchanges and circuit groups; and

- the routing rules, as described in the traffic dispersion evaluation on a "per exchange" basis.

The evaluation of the traffic dispersion on a network basis is applicable when the exchange traffic dispersion has been evaluated on at least two exchanges connected to each other by means of a circuit group.

Of course, without prejudice to the underlying principles of the invention, the details and embodiments may vary, even significantly, with respect to what has been described by way of example only, without departing from the scope of the invention as defined in the claims that follow.